HARD PROBE RESULTS FROM PHENIX

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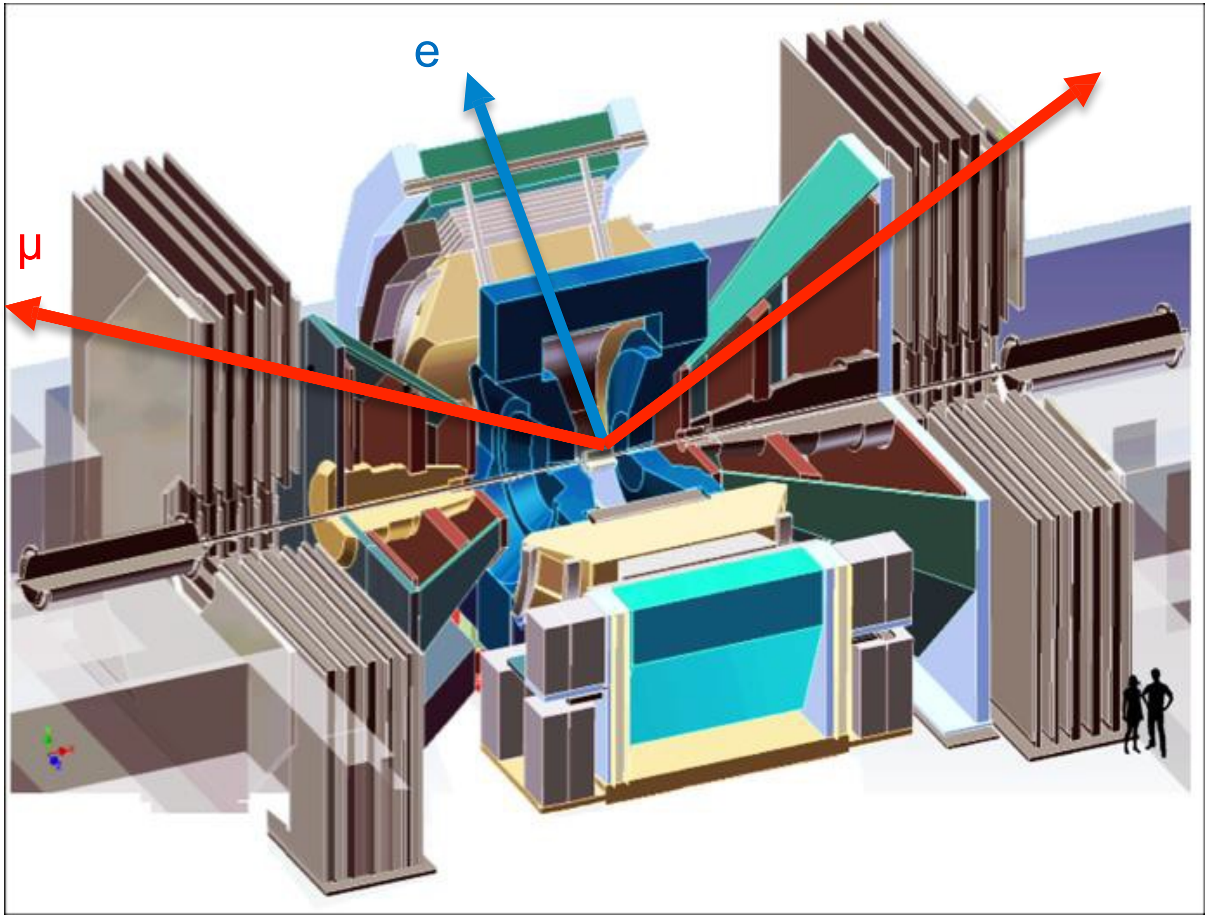
LANL

Overview

- Thermal Photons
- Flow in Small systems
- Open heavy flavor and J/Ψ

The PHENIX Detector

- **Central Electrons**
  - $|\eta| < 0.35$
  - $\Delta\phi = \pi$
  - Tracking: DC, PC
  - eID: RICH, EMcal



- **Forward Muons**
  - $1.2 < |\eta| < 2.2$
  - $\Delta\phi = 2\pi$
  - ~10λ absorber
  - Tracking: wire chamber
  - MuID: 5 layers of steel and Iarocci tube planes

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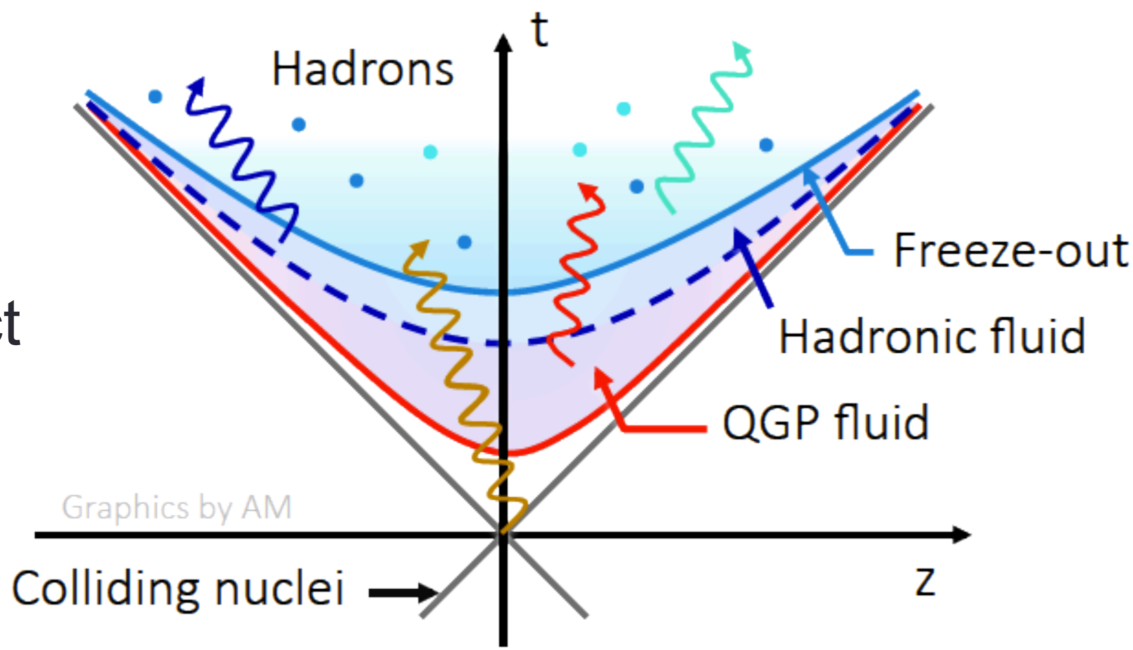
Photons

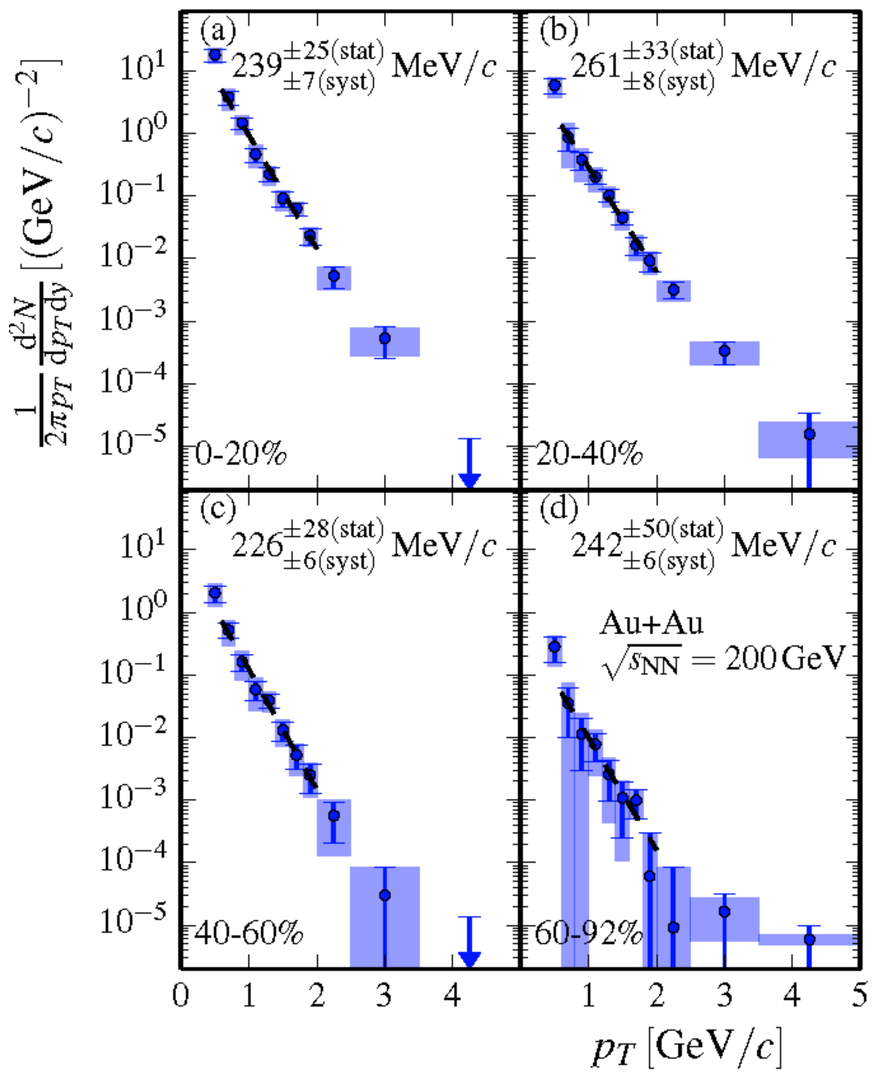
Photons don’t interact



Thermal photon spectra

- Thermal photon spectra are obtained by subtracting hard photons from all direct photon spectra
  - Hard photon contribution is estimated from p+p times Ncoll
- Fitting to low p_T region gives T~240MeV/c, almost independent of centrality
- The Slope parameter reflects the convolution of the instantaneous rates with the time-dependent temperature.
  - One has to assume time profile to obtain the temperature at given time.

arXiv:1405.3940, PRC91, 064904 (2015)



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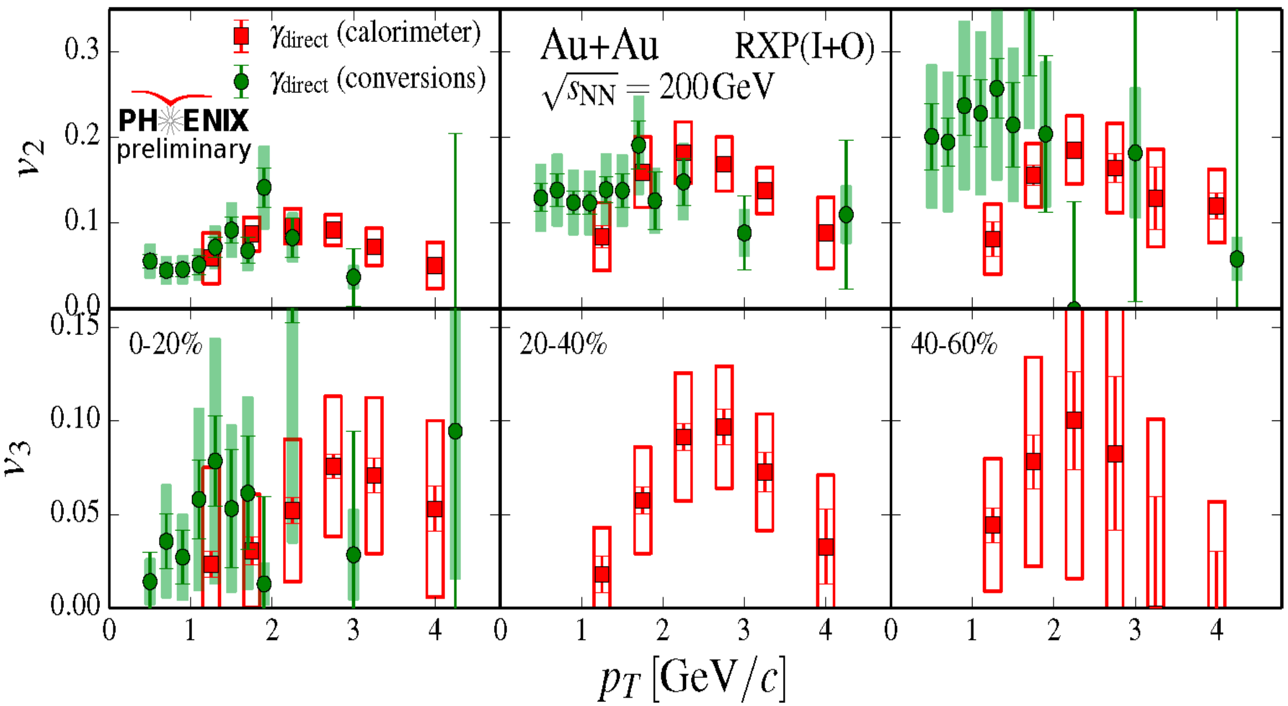
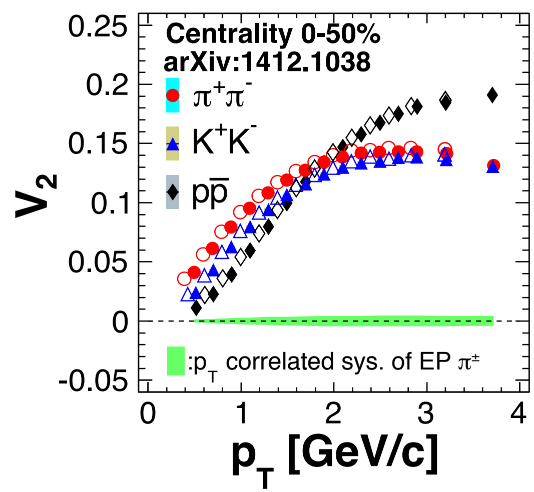
Recent results on photon v_2 and v_3

- Some centrality dependence in v_2, weak dependence in v_3
  - Similar trend as for charged hadrons (PRL 107, 252301 (2011)) and π^0.





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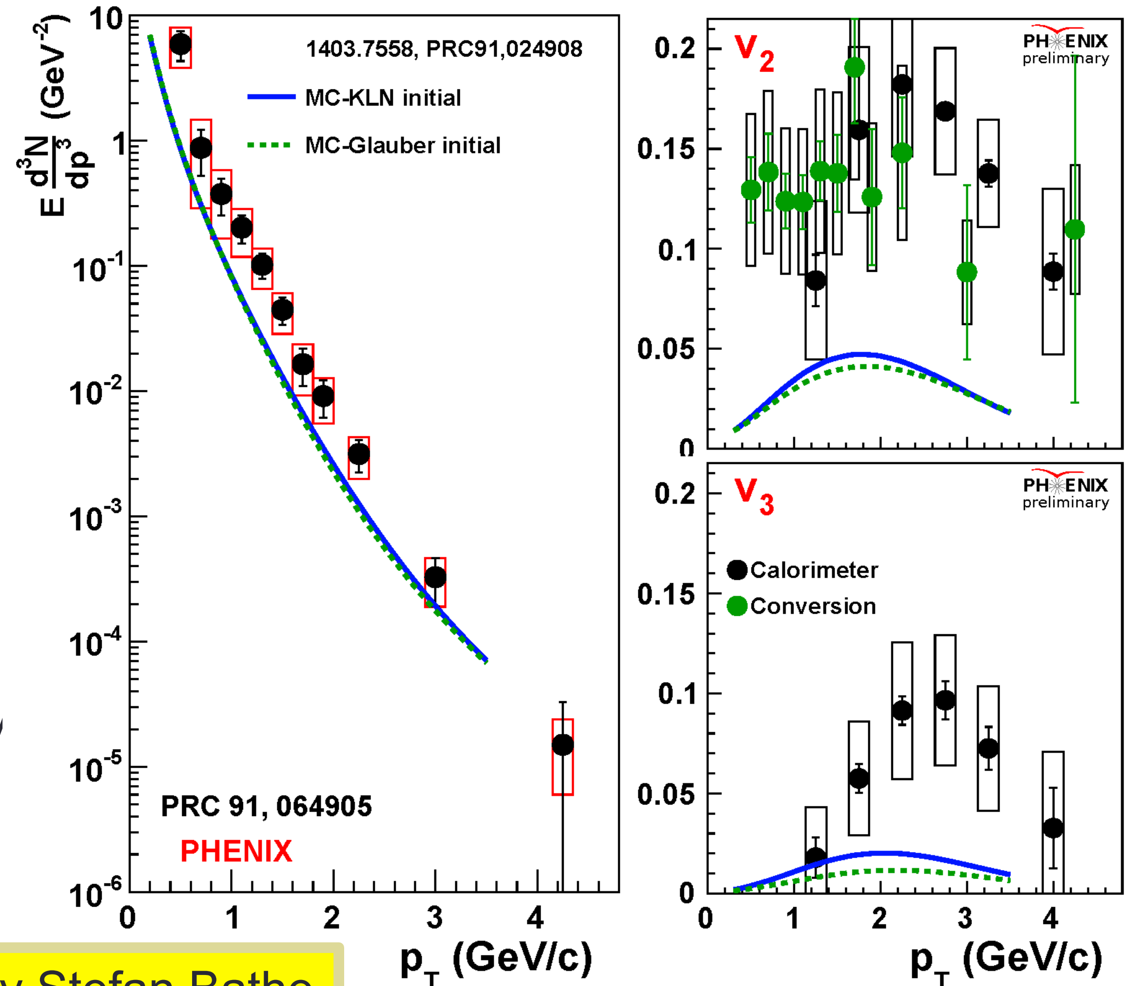
Models have a hard time, so far…

- C. Shen et al.,
- PRC 91, 024908 (2015)
- Thermal photon contribution calculated by 3+1D Hydro including viscous correction
- Two Initial conditions are considered
- v_2 and v_3 are for thermal + pQCD photons
- Blue shift effect is naturally included in the hydro-evolution

Thermal γ p_T spectra, direct γ v_2,v_3, Au+Au@200GeV, 20-40%



See talk by Stefan Bathe

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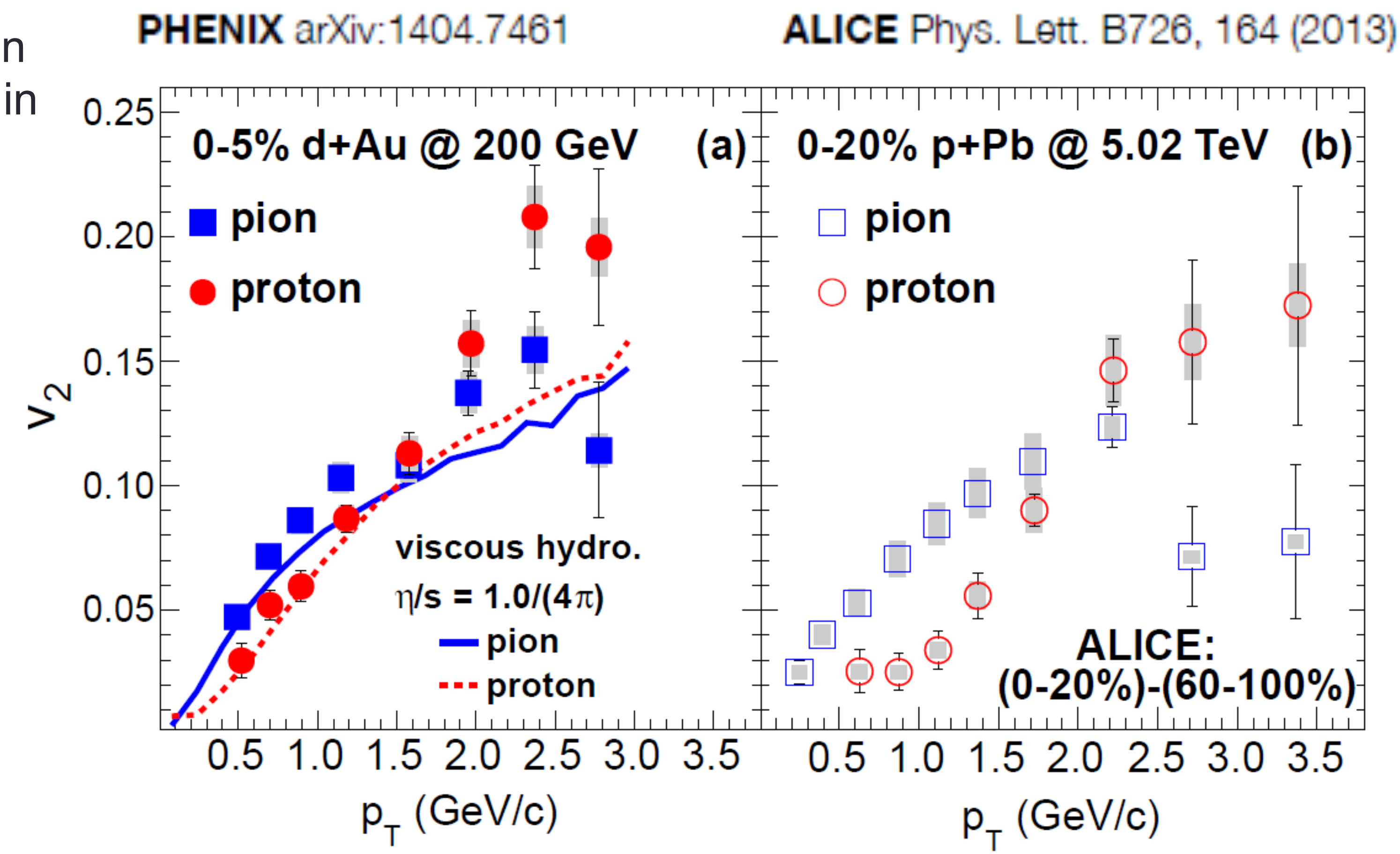
Flow in Small Systems

Flow in small systems

We have seen v_2 of π and p in d+Au



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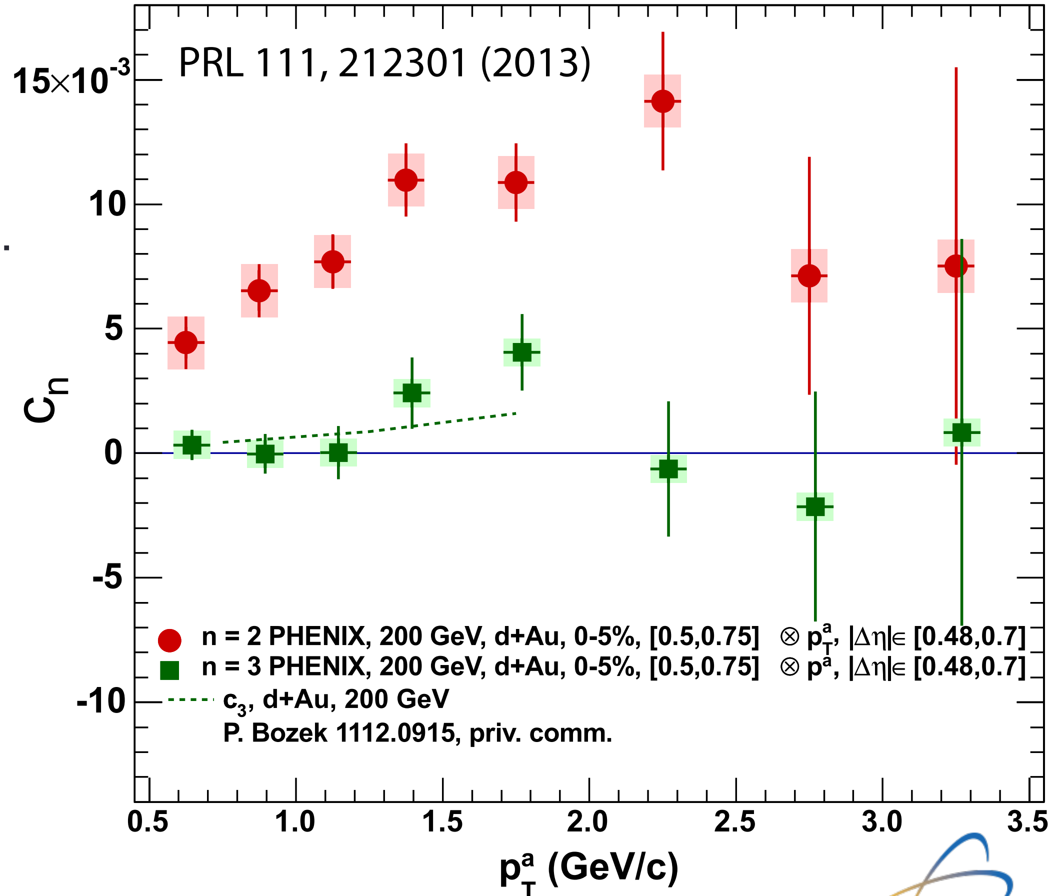
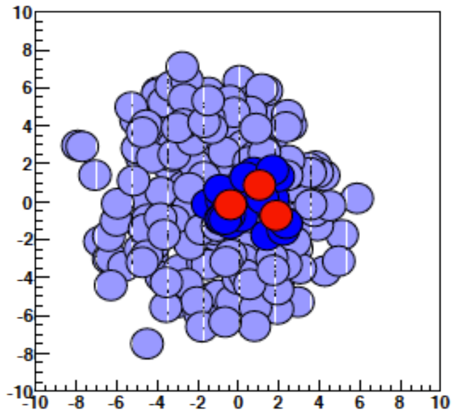
Flow in small systems

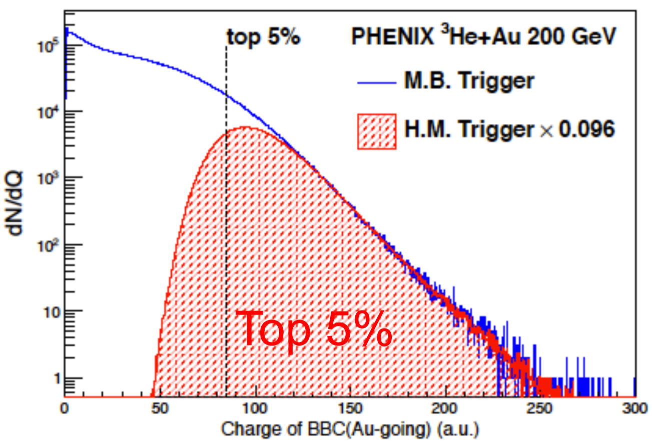
But c3 in d+Au is small…

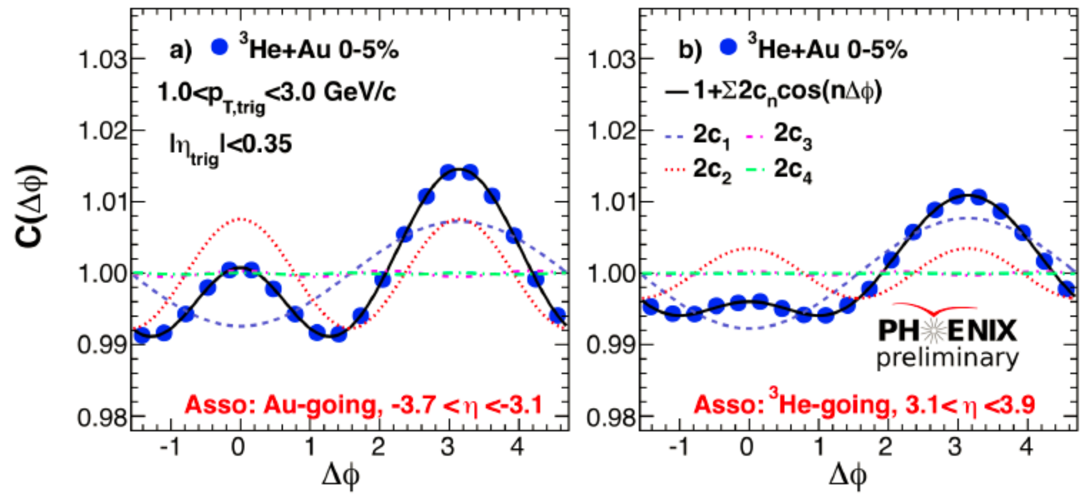


Small system flow - ^{3}He+Au



Make a high-multiplicity trigger:





Au-going d-going

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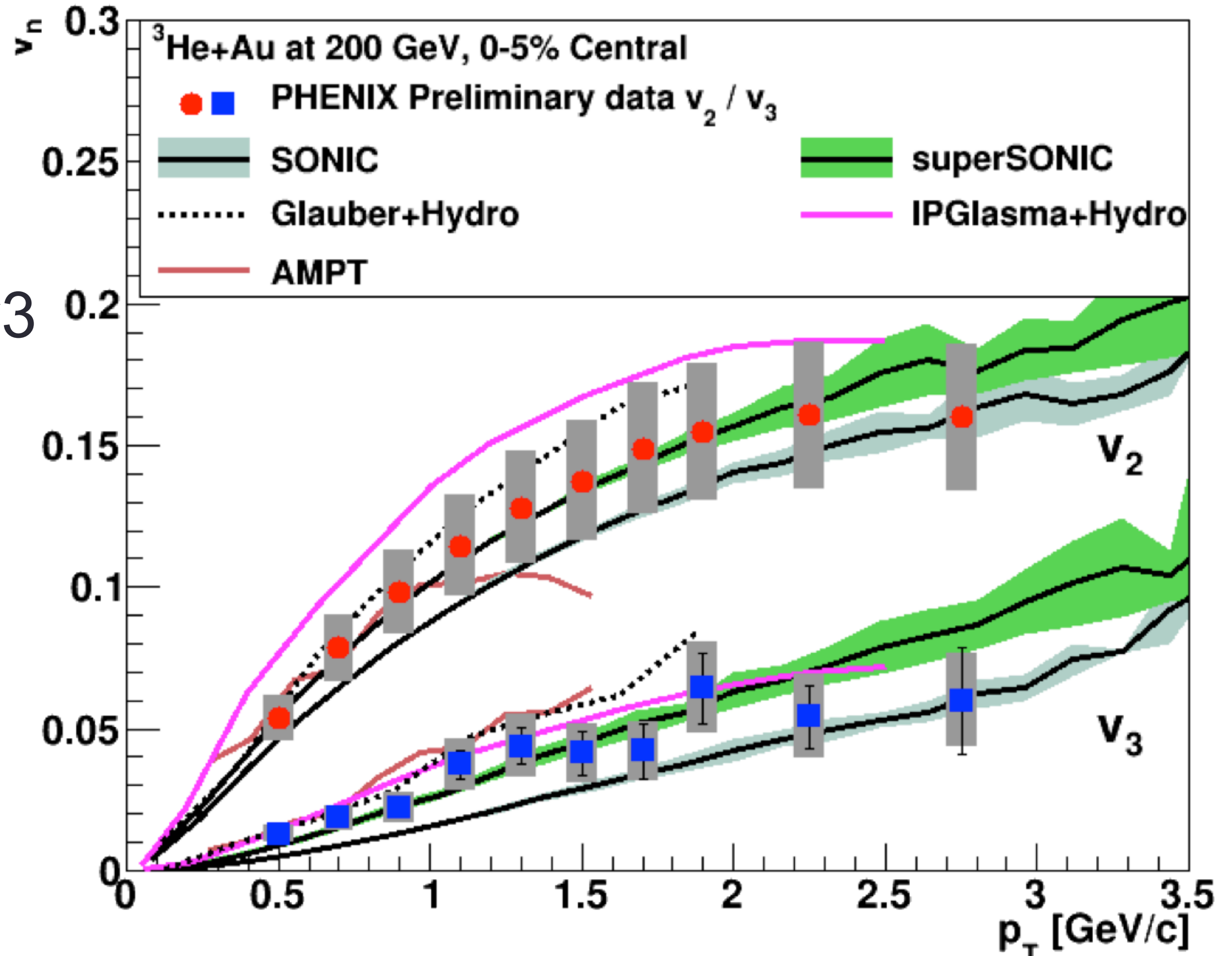
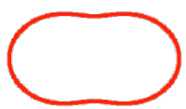
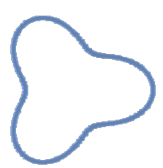
Flow in ^{3}He+Au

v2 and v3







Talk by Anne Sickles

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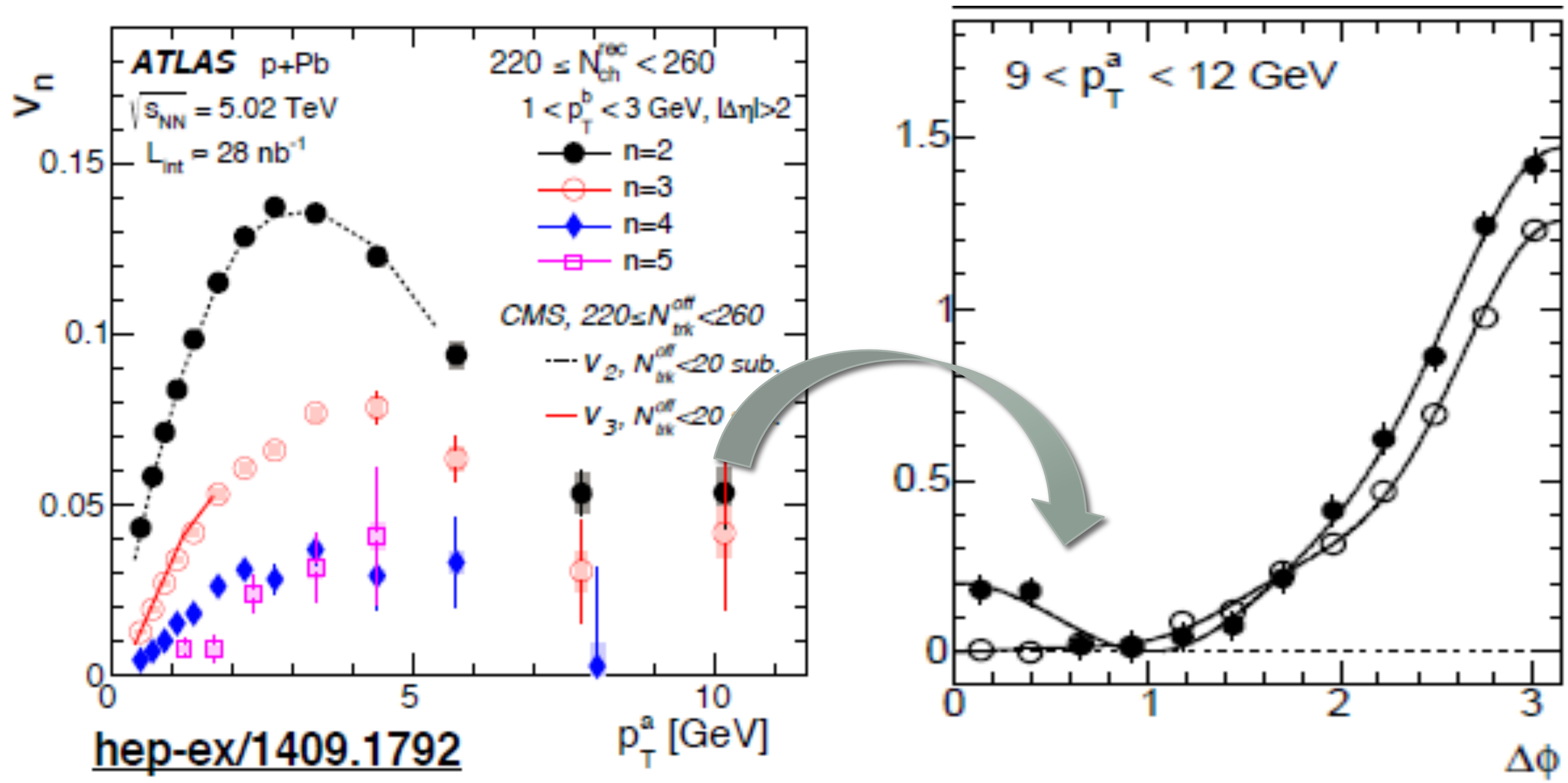
Flow-like patterns in p(d)+A are surprising

Significant v_2 to high p_T is also surprising



hep-ex/1409.1792

ATLAS sees 5% v_2 at p_T ~ 10 What can we see at RHIC in d+Au collisions?

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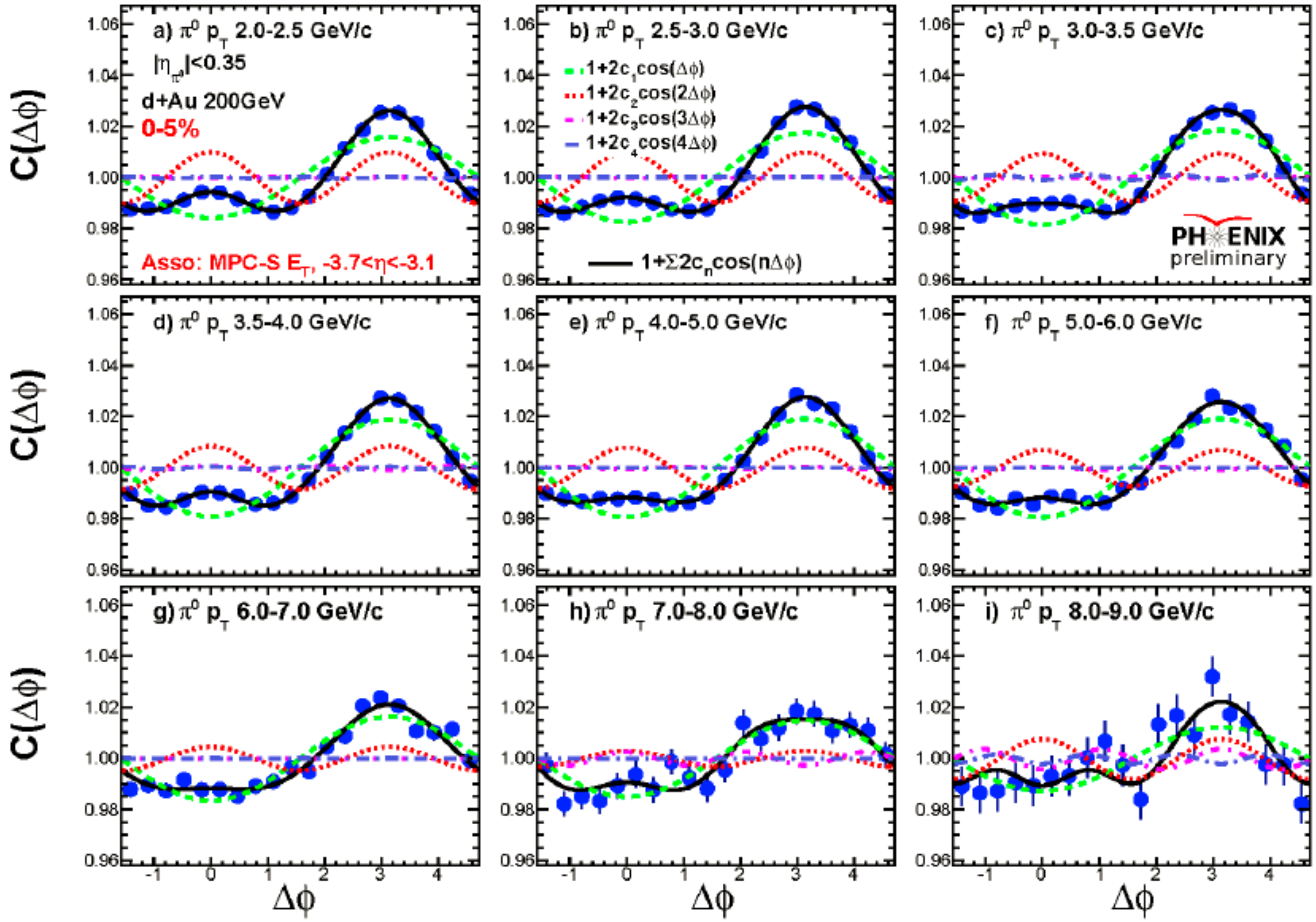
Near-side ridge in d+Au

How high in pT is there a peak contribution at $\Delta\phi$ = 0…

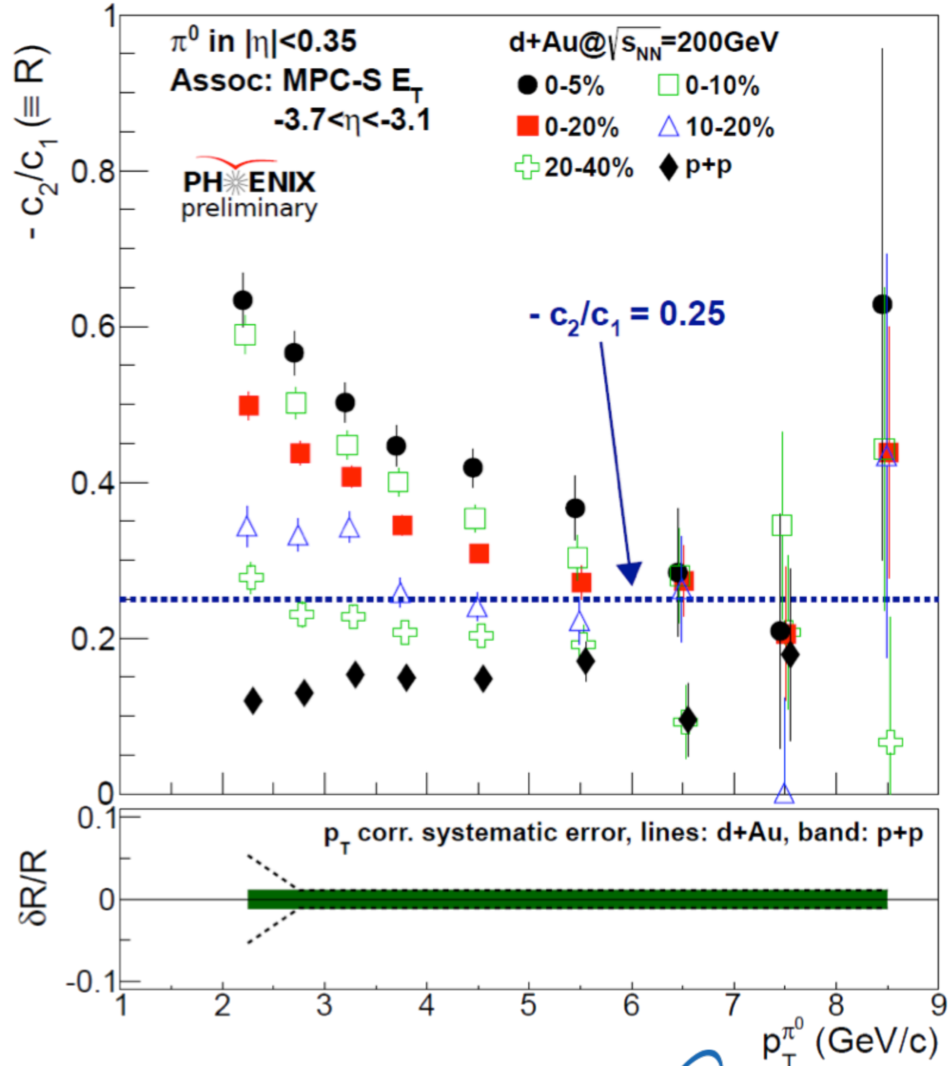


Correlations between neutral pions and particles 3 units in rapidity away.

In d+Au, ridge persists to pT~6GeV

For correlation function described by *only* c1 and c2, there is a local maximum at $\Delta\phi$ = 0 when $-c2/c1 > 0.25$

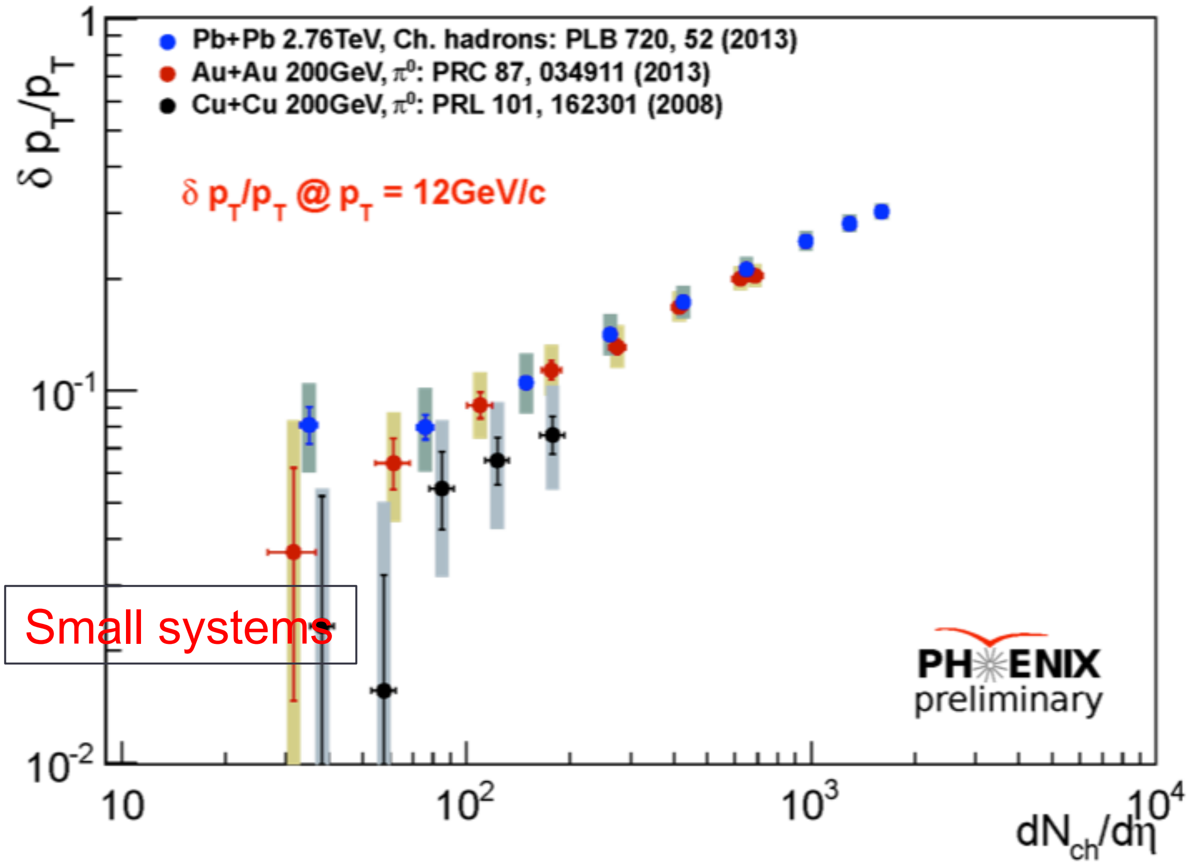
No near-side ridge in p+p MB.

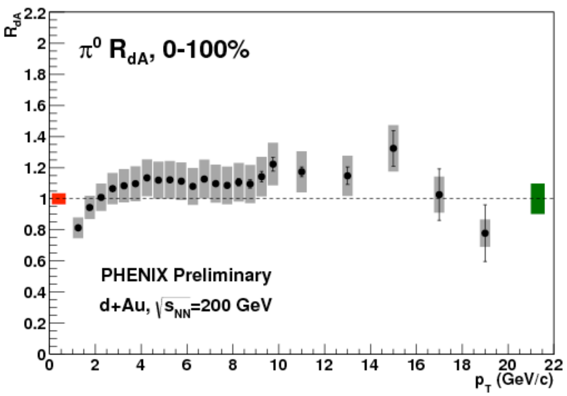


Jet quenching in A+A

Do hard probes suffer Eloss in small systems? Likely not

Fractional momentum loss vs. $dN_{ch}/d\eta$





Also, R_{dA} ~1

So where does the 'flow' come from?

See talk by Klaus Dehmelt

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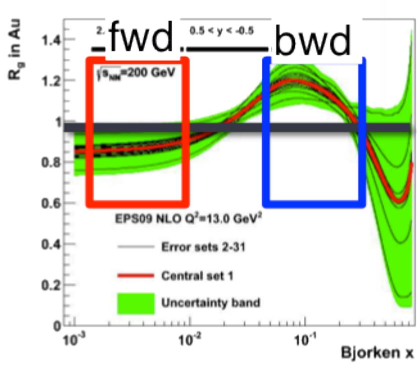
Open Heavy Flavor

Muons at Forward/Backward Rapidity

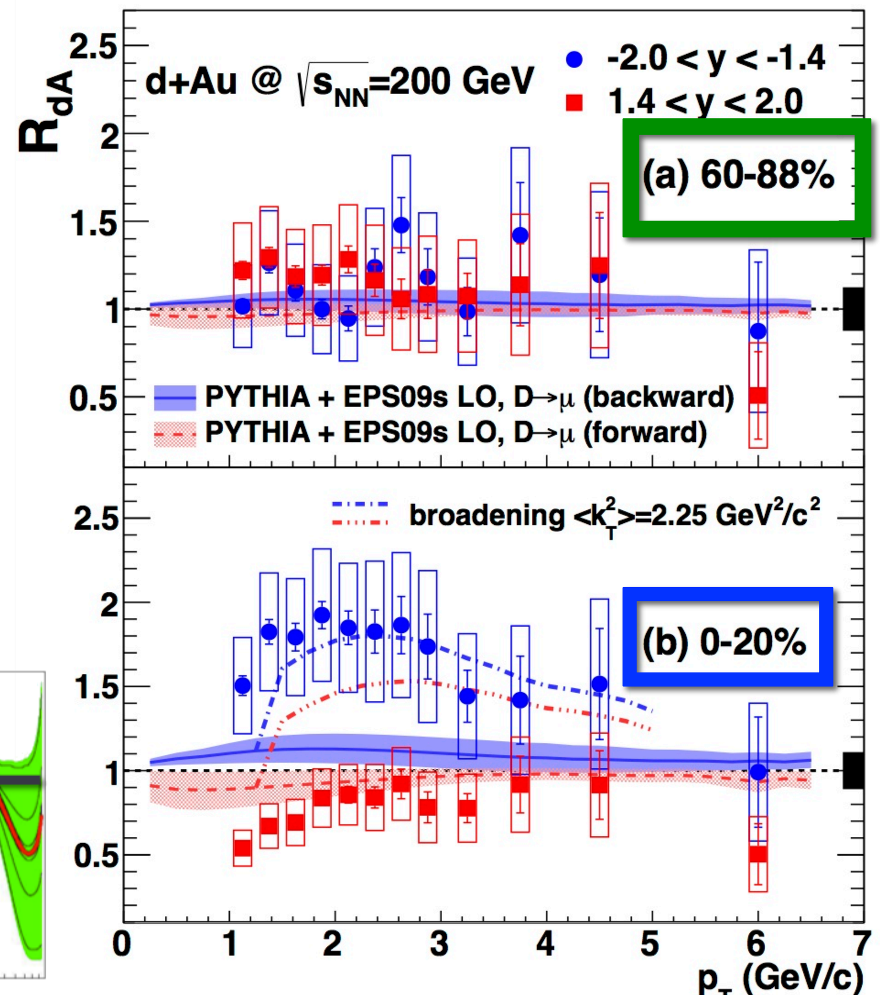
Peripheral:
Consistent with
scaled p+p results

Central:
Enhancement
at backward rapidity
Anti-Shadowing Region

Suppression
at forward rapidity
Shadowing Region



R_g from EPS09



Phys. Rev. Lett. 112, 252301 (2014)

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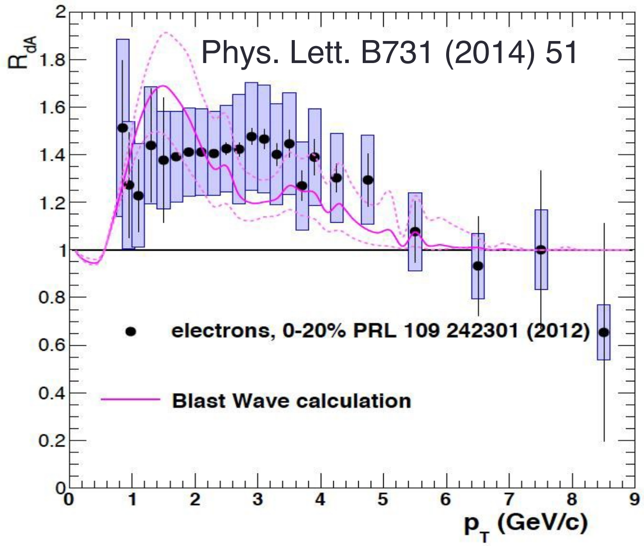
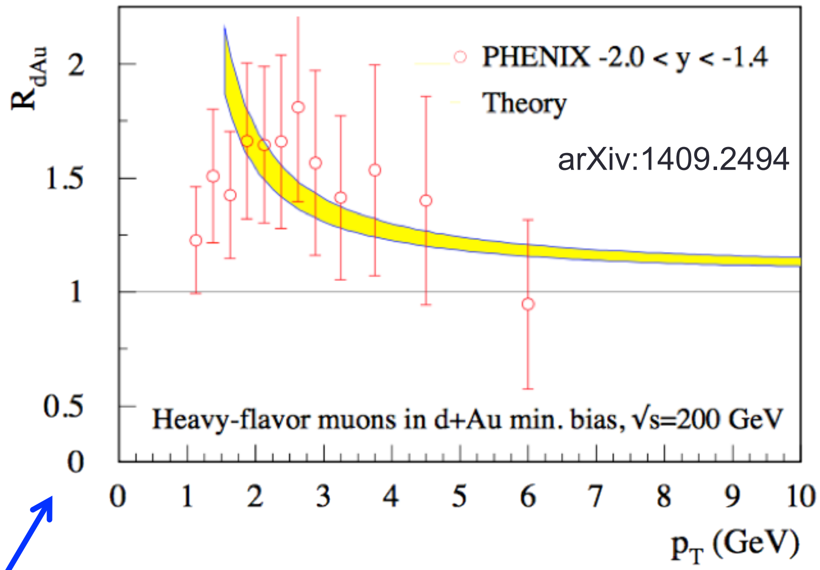
Some calculations

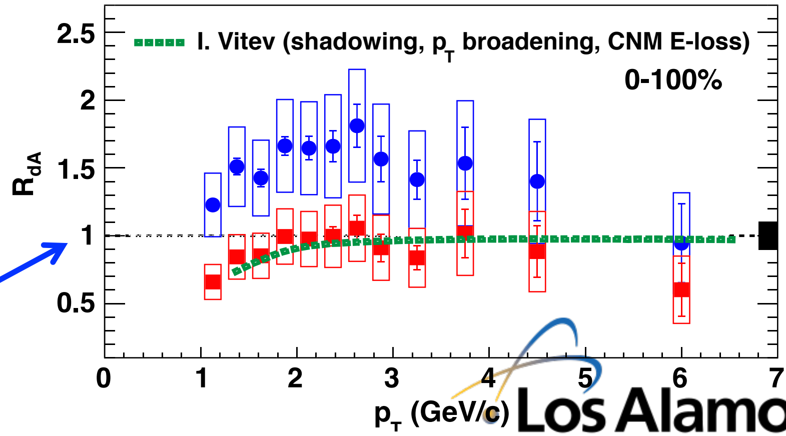




Radial flow also qualitatively reproduce the enhancement

pQCD calculation considering incoherent scattering reproduces the enhancement at backward rapidity

As well as forward, with shadowing, CNM, pT broadening



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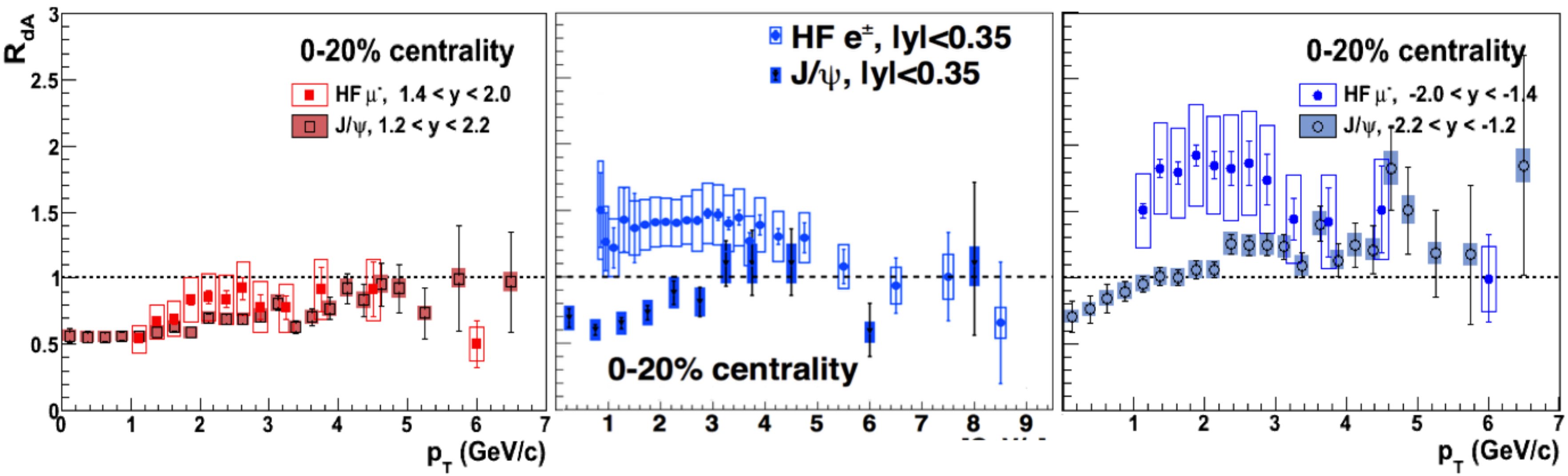
Heavy Flavor Comparison with *J/ψ*

d-Going **Mid-Rapidity** **Au-Going**



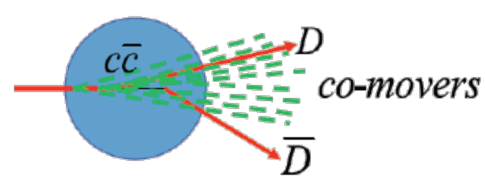
Similar suppression at forward rapidity

- Low co-mover density
- Same suppression mechanism

Different behavior at mid and backward rapidity

Different suppression mechanism

Larger nuclear break-up effects at higher-density region

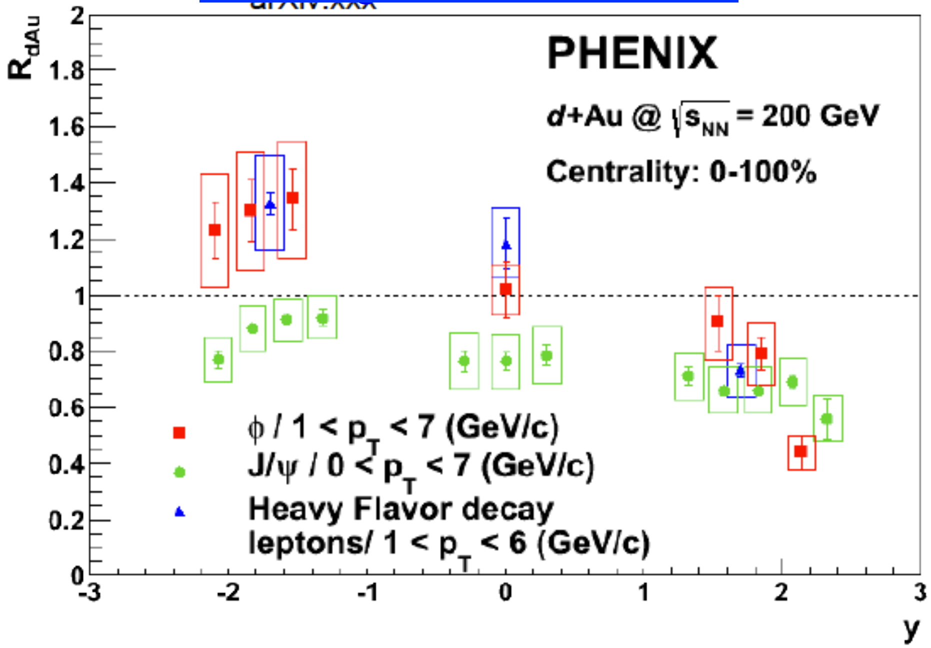


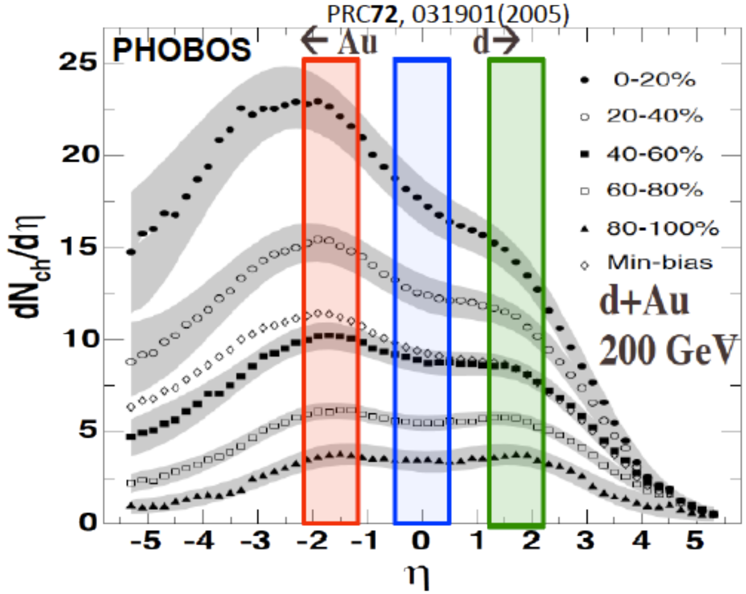
Talk by Matt Snowball

J/ψ: Phys. Rev. C. 87, 034904 (201

Phi follows heavy flavor

arxiv.org/abs/1506.08181

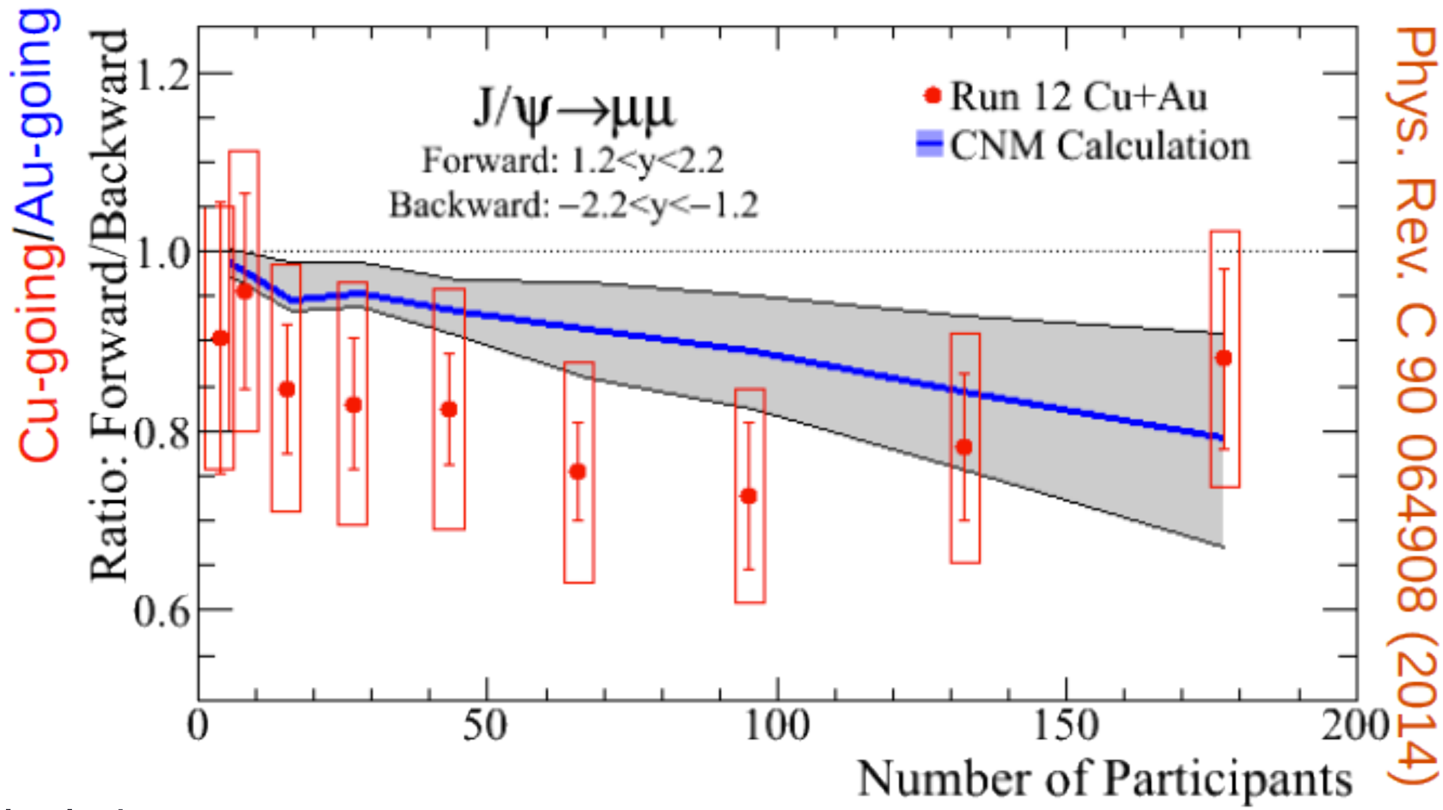




Different processes act on open HF and phi. The match
May be a coincidence.

Talk by Murad Sarsour

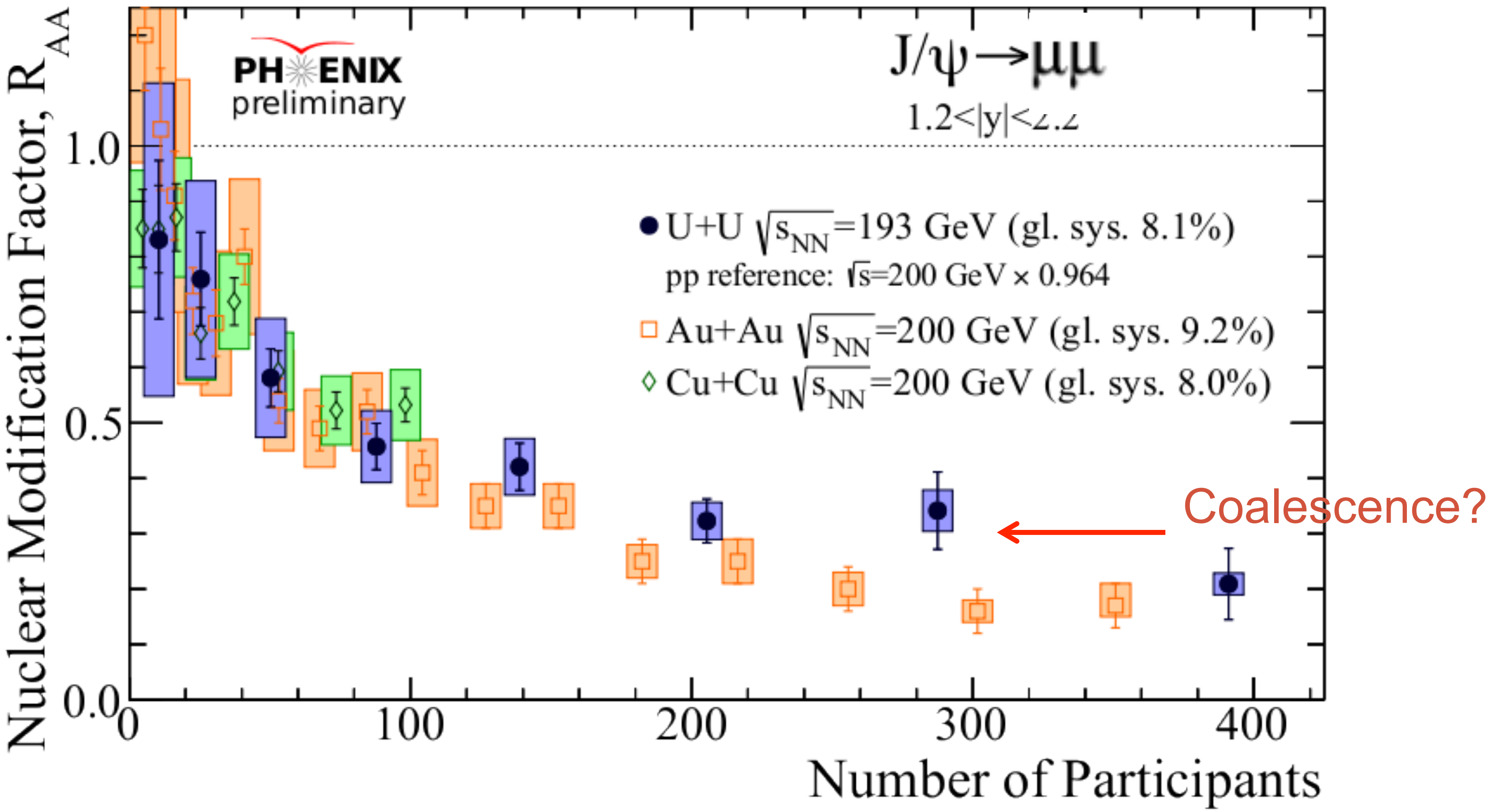
Cold Nuclear Matter Effects



Calculation:
PRC 84 044911 (2011)
Nagle, Frawley, Levy, Wysocki
Only shadowing, EPS09

Hot NM effects ~same in Cu, Au
Cold nuclear matter effect?

Other effects



Talk by Aneta Iordanova

Wealth of data, many effects at work

- Many different systems: p+p … U+U
- Energies 17GeV – 2.7 TeV
- All of them are needed to disentangle the many different effects of hot and cold nuclear matter

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Thank you

Parallel talks

- ‘Hadron Correlations in ^{3}He+Au and d+Au Collisions at PHENIX’
  Anne Sickles, Leacock 232: Monday 15:50
- ‘Cold nuclear matter effects on low mass vector mesons and heavy flavor production in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV’
  Murad Sarsour, Leacock 232: Monday 16:30
- ‘Measurement of single leptons from heavy flavor decays in the PHENIX experiment’
  Matt Snowball, Leacock 219: 10:50
- ‘System size dependence of J/ψ production at RHIC’
  Aneta Iordanova, Leacock 219: Tuesday 11:30
- ‘High p_T single identified particles in various systems, various collision energies, and several scaling variables’
  Klaus Dehmelt, Leacock 26: Wednesday 09:00
- ‘Direct photon production and azimuthal anisotropy measured in PHENIX’
  Stefan Bathe, Leacock 232: Wednesday 10:50

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Back up

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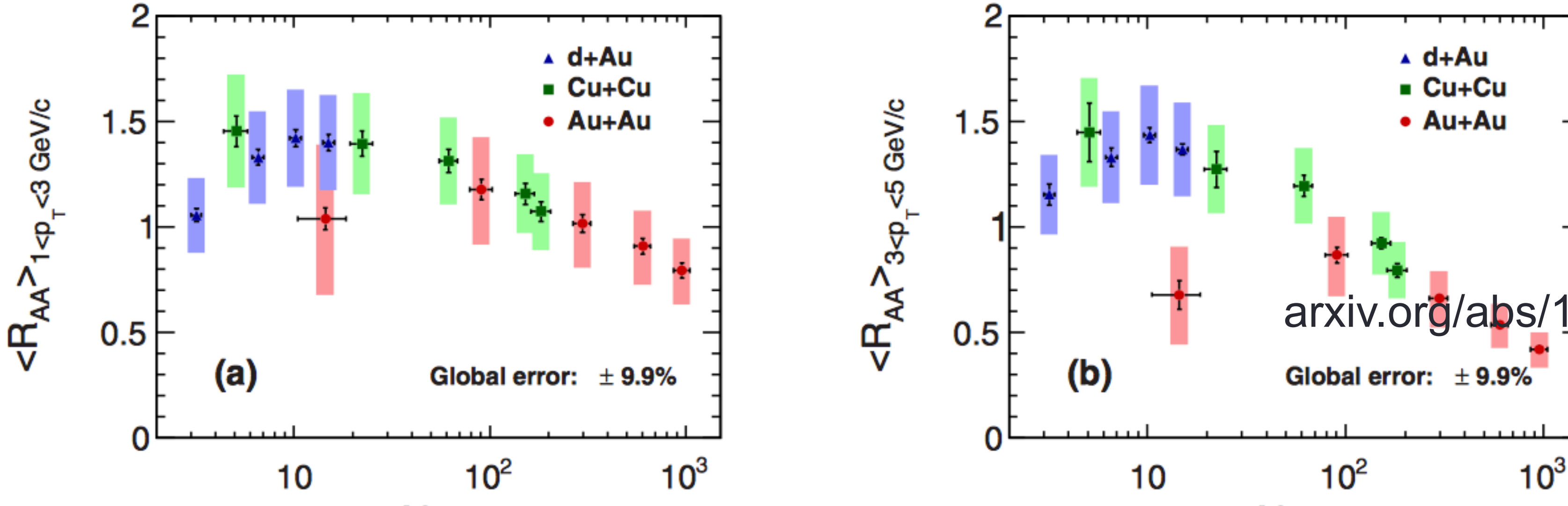
Evolution of HF e production



arxiv.org/abs/1404.224

PRC 90 034903 (2014)

- The nuclear modification factors for HF electrons at mid-rapidity in d+Au, Cu+Cu, and Au+Au
- Nice trend from smaller systems, d+Au and peripheral Cu+Cu, ***where enhancement effects are dominating*** to central Cu+Cu and Au+Au collisions, ***where suppression effects take over***

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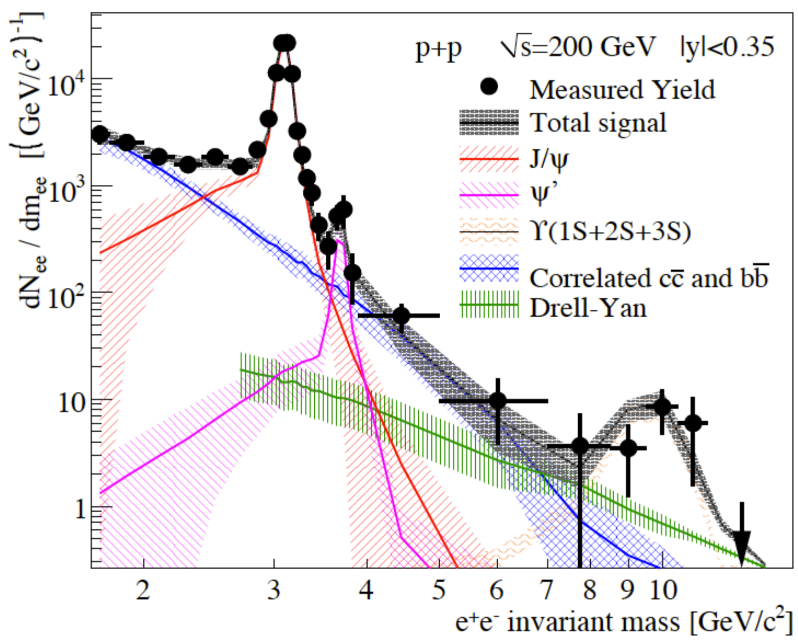
p+p $\sqrt{s}$=200 GeV |y|<0.35
Measured Yield
Total signal
J/ψ
ψ'
ϒ(1S+2S+3S)
Correlated $c\bar{c}$ and $b\bar{b}$
Drell-Yan
dN_{ee}/dm_{ee} [(GeV/c^2)$^{-1}$]
e^+e^- invariant mass [GeV/c^2]